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1. REPORT DATE <b>13 OCT 2010</b>		2. REPORT TYPE <b>N/A</b>		3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>Relative Permittivity to Measure Free Water in Fuel</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) <b>Joel Schmitgal</b>				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000, USA</b>				8. PERFORMING ORGANIZATION REPORT NUMBER <b>21386</b>	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) <b>US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000, USA</b>				10. SPONSOR/MONITOR'S ACRONYM(S) <b>TACOM/TARDEC</b>	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S) <b>21386</b>	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>The original document contains color images.</b>					
14. ABSTRACT <b>The objective of this effort was to evaluate feasibility for measuring relative permittivity (dielectric constant) to evaluate the free water content in petroleum fuels.</b>					
15. SUBJECT TERMS <b>Relative Permittivity, Dielectric Constant, Fuel, JP-8, Diesel, Free Water</b>					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>SAR</b>	18. NUMBER OF PAGES <b>11</b>	19a. NAME OF RESPONSIBLE PERSON
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Registration No.

21386



## Relative Permittivity to Measure Free Water in Fuel

Joel Schmitigal

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release; distribution is unlimited.

**October 2010**

U.S. Army Tank Automotive Research,  
Development, and Engineering Center  
Detroit Arsenal  
Warren, Michigan 48397-5000

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# **U.S. Army Tank Automotive Research Development and Engineering Center**

Warren, Michigan 48397-5000

## **Relative Permittivity to Measure Free Water in Fuel**

**Joel Schmitigal**  
**Force Projection Technology**

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## 1. Introduction

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The objective of this effort was to evaluate feasibility for measuring relative permittivity (dielectric constant) to evaluate the free water content in petroleum fuels. The relative permittivity is the ratio of the permittivity, resistance to forming an electrical field, of a substance of interest to the permittivity of a vacuum. Simply put the relative permittivity is a measure of a fluids ability to resist an electrical charge from conducting through it. Relative permittivity is defined as:

$$\epsilon_r(\omega) = \frac{\epsilon(\omega)}{\epsilon_0}$$

Where  $\epsilon(\omega)$  is the frequency-dependent absolute permittivity of the fluid being measured, and  $\epsilon_0$  is the constant of permittivity in a vacuum.

US Army TARDEC had previously investigated the use of sensors measuring relative permittivity to determine the condition of diesel engine oil onboard a vehicle (1). In these evaluations relative permittivity measurements were shown to have the ability to track changes in water content, although not independently of other changes in engine oil properties.

Petroleum products have a relative permittivity in the range of 1.7-2.3 while water has a relative permittivity of ~80. These vast differences makes utilizing this measurement very enticing for measuring the contamination of fuel by water.

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## 2. Approach

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### 2.1. Free Water Detection

The evaluation of determining the feasibility for measuring relative permittivity to detect the free water content in petroleum fuels was performed by immersing a sensor in a Jet A fuel sample and purposely adding known concentrations water and measuring the relative permittivity after 1 minute of ultrasonic mixing followed by vigorous stirring. The relative permittivity was measured 5 times for each test point, and averages reported. The CSI Oil View Model 5500 from Emerson Process Management (Knoxville, TN) was utilized to perform this evaluation.

### 2.2. Fuel Baseline Relative Permittivity

Measurements of a small sample size of fuels were measured to establish a set of baseline measurements of the various fuel types. These fuels included three fuels commonly utilized by the U.S. Army, Diesel Fuel No. 2, JP-8, and Jet A fuels. The relative permittivity was measured 5 times for each test point, and averages reported. The CSI Oil View Model 5500 from Emerson Process Management (Knoxville, TN) was utilized to perform this evaluation.

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### 3. Analysis

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#### 3.1. Free Water Detection

Each of the fuel samples containing a known amount of free water was measured five (5) times. the average relative permittivity is given in Table 1. A minimal amount of change in the relative permittivity was displayed with the higher levels of free water in the fuel. The addition of the free water was clearly visible to the naked eye as shown in Figure 1.

PPM free water	Relative Permittivity
0	2.08
10	2.08
20	2.08
50	2.08
100	2.09
200	2.09
999	2.09

Table 1. Relative permittivity of fuel in relation to amount of free water in the fuel



Figure 1. Zero (0) PPM free water (left) vs 999 PPM free water (right)

### 3.2. Fuel Baseline Relative Permittivity

The relative permittivity sensor was used to measure eight (2) fuels, 2 Jet A samples, 3 Diesel No. 2 samples, and 3 JP-8 samples, to determine the variation of relative permittivity among the fuel samples.

Fuel Type	Relative Permittivity
Diesel No. 2	2.20
Diesel No. 2	2.18
Diesel No. 2	2.04
JP-8	2.12
JP-8	2.27
JP-8	2.10
Jet A	2.08
Jet A	2.14

Table 2. Relative permittivity of 8 fuel samples

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## 4. Conclusion

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The variation in the baseline measurement of relative permittivity among the Jet A fuels, Diesel No. 2 fuels and JP-8 fuels is greater than the change in relative permittivity that occurs when 1000 ppm of free water is added to a fuel. This data indicates that measuring the relative permittivity of a fuel is not able to provide an accurate correlation to the amount of free water present in the sample of interest or a change in the free water content of a known sample.

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## References

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1. *Evaluation of Sensors for On-Board Diesel Oil Condition Monitoring of U.S. Army Ground Equipment.* **Schmitigal, Joel and Moyer, Steve.** Detroit : Society of Automotive Engineers, 2005.